CLAIMS

1. A stacked-layer type photoelectric conversion device comprising a plurality of photoelectric conversion units (3; 5) stacked on a substrate (1), each of which includes a one conductivity-type layer (31; 51), a photoelectric conversion layer (32; 52) of substantially intrinsic semiconductor, and an opposite conductivity-type layer (33; 53) in this order from a light incident side, wherein

at least one of said opposite conductivity-type layer (33) in a front photoelectric conversion unit (3) arranged relatively closer to the light incident side and said one conductivity-type layer (51) in a back photoelectric conversion unit (5) arranged adjacent to said front photoelectric conversion unit (3) includes a silicon composite layer (4) at least in a part thereof, and

said silicon composite layer (4) has a thickness of more than 20 nm and less than 130 nm and an oxygen concentration of more than 25 atomic % and less than 60 atomic %, and includes silicon-rich phase parts in an amorphous alloy phase of silicon and oxygen.

2. The stacked-layer type photoelectric conversion device according to claim 1, wherein said silicon-rich phase part includes a silicon crystal phase.

3. The stacked-layer type photoelectric conversion device according to claim 1, wherein said silicon-rich phase part includes doped amorphous silicon.

4. The stacked-layer type photoelectric conversion device according to claim 1, wherein refractive index of said silicon composite layer regarding light of 600 nm wavelength is more than 1.7 and less than 2.5.

5. The stacked-layer type photoelectric conversion device according to claim 1,

wherein said substrate is transparent, and a reflection spectrum of light having passed through the substrate and entered said stacked photoelectric conversion units has at least one maximal value and at least one minimal value of reflectance in a wavelength range of 500 nm to 800 nm, and a difference between said maximal value and said minimal value is at least 1%.

6. The stacked-layer type photoelectric conversion device according to claim 1, wherein dark conductivity of said silicon composite layer is more than 10^{-8} S/cm and less than 10^{-1} S/cm.

7. The stacked-layer type photoelectric conversion device according to claim 1, wherein in said silicon composite layer, an intensity ratio of a TO mode peak derived from crystalline silicon phase parts to a TO mode peak derived from said amorphous alloy phase, measured by Raman scattering, is more than 0.5 and less than 10.

8. The stacked-layer type photoelectric conversion device according to claim 1, wherein an optical energy gap of said silicon composite layer is at least 2.2 eV.

9. The stacked-layer type photoelectric conversion device according to claim 1, wherein in said silicon composite layer, an energy difference between upper most energy of a photoelectron having suffered interband excitation loss of O1s and peak energy of the O1s photoelectron, measured by X-ray photoelectron spectroscopy, is at least 2.2 eV.

10. The stacked-layer type photoelectric conversion device according to claim 1, wherein a dopant atom concentration in said silicon composite layer is in a range from 3×10^{20} cm^{-3} to 1.8×10^{21} cm^{-3}.

11. A method of forming the stacked-layer type photoelectric conversion device of claim 1, wherein said substrate, having said silicon composite layer deposited to a part of its total thickness in a plasma CVD reaction chamber, is temporarily taken out to expose a surface of said silicon composite layer to the ambient air, and then after said substrate is introduced again into a plasma CVD reaction chamber, the remaining part of the total thickness of said silicon composite layer is deposited.

12. The method according to claim 11, wherein said substrate is taken out from said plasma CVD reaction chamber to the ambient air after at least 60% of the total thickness of said silicon composite layer is deposited.

13. A method for forming the stacked-layer type photoelectric conversion device of claim 1, wherein a mixing ratio of doping source gas to silicon source gas for deposition of said silicon composite layer in a plasma CVD reaction chamber is in a range from 0.012 to 0.07.

14. An integrated type photoelectric conversion module, wherein

a first electrode layer (103), a plurality of photoelectric conversion unit layers (104a; 104b) and a second electrode layer (106) successively stacked on a substrate (102) are separated by a plurality of isolation grooves (121; 122) to form a plurality of photoelectric conversion cells (110), and the cells are electrically connected in series with each other via a plurality of connection grooves (123),

each of said photoelectric conversion cells has a plurality of stacked photoelectric conversion units each including a one conductivity-type layer, a photoelectric conversion layer of substantially intrinsic semiconductor and an opposite conductivity-type layer in this order from a light-incident side,

at least one of said opposite conductivity-type layer in a front photoelectric conversion unit (104a) arranged relatively closer to the light-incident side and said one

conductivity-type layer in a back photoelectric conversion unit (104b) arranged adjacent to the front photoelectric conversion unit includes a silicon composite layer (107) at least in a part thereof, and

said silicon composite layer (107) has a thickness of more than 20 nm and less than 130 nm and an oxygen concentration of more than 25 atomic % and less than 60 atomic %, and includes silicon-rich phase parts in an amorphous alloy phase of silicon and oxygen.

15. The integrated type photoelectric conversion module according to claim 14, wherein said first electrode layer (103) is separated into a plurality of regions corresponding to said plurality of photoelectric conversion cells (110) by a plurality of first isolation grooves (121), said plurality of photoelectric conversion unit layers (104a; 104b) and said second electrode layer (106) are separated into a plurality of regions corresponding to said plurality of cells by a plurality of second isolation grooves (122), and a connection groove (123) is provided between said first isolation groove (121) and said second isolation groove (122) to electrically connect said first electrode of one of said cells with said second electrode of its neighboring cell.